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MINERνA: PRESENT AND FUTURE

(on behalf of MINERνA collaboration)

Overview

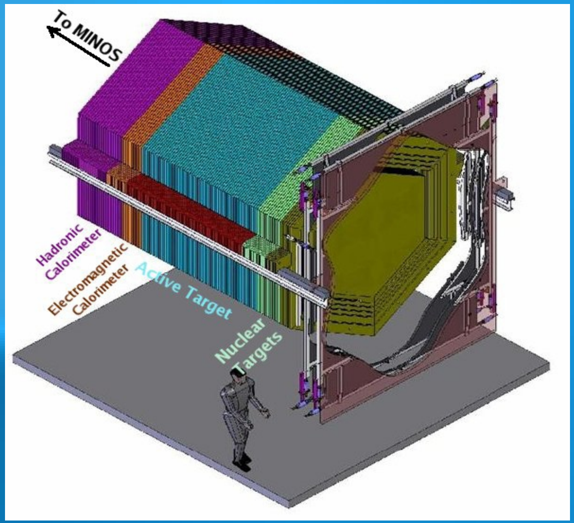
- Experiment overview
- Physics goals
- Neutrino flux
- Detector description
- Event rates
- Calibration
- Simulation
- Reconstruction
- Current status
- Future plans

Experiment overview

- **Location: FNAL, MINOS underground (330 ft) cavern**

- **Structure: segmented scintillator with electromagnetic and hadronic calorimetry regions as well as nuclear targets**

- **Goals: to measure the cross-sections of neutrino interactions with high precision; to examine the nuclear medium effects in neutrino-induced interactions**



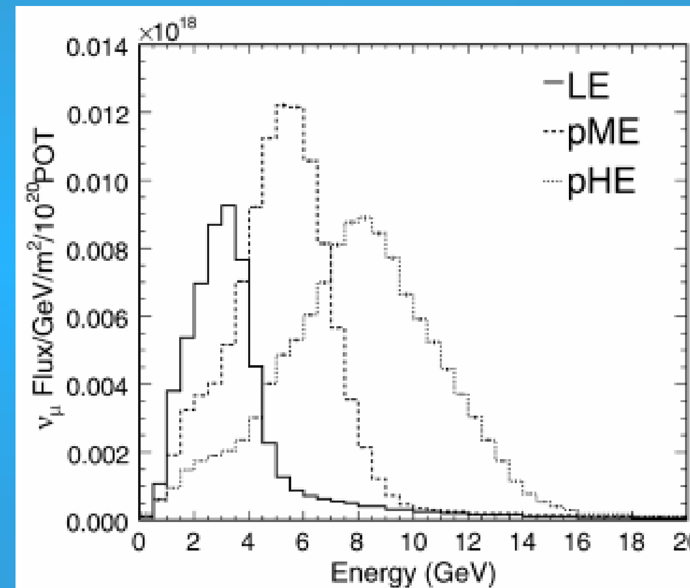
Physics goals

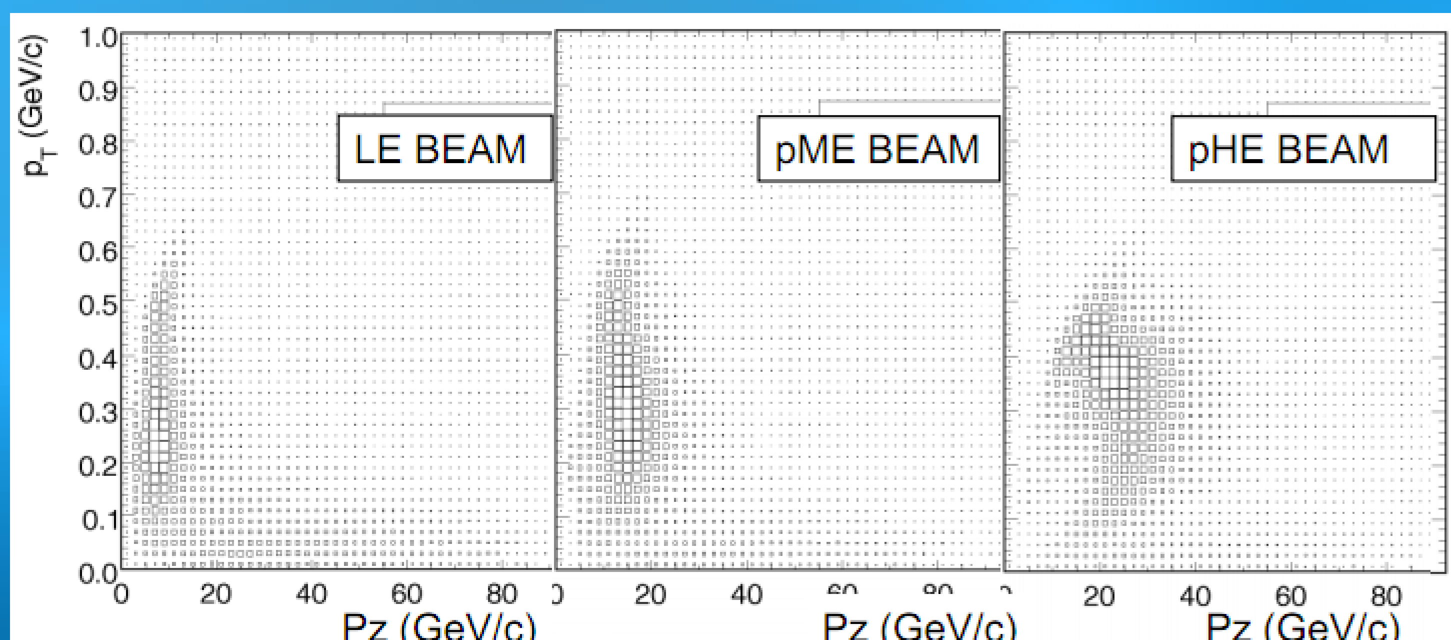
- Precision cross-section measurements for various neutrino interaction channels (quasi-elastic, resonant and coherent pion production, DIS)
- Study of nuclear effects in neutrino interaction (final states multiplicities, hadronic energy as a function of A)
- Precision measurement of strange-particle production channels (q^2 dependence, resonant structure, polarization states)

Neutrino flux

Several methods to obtain the flux:

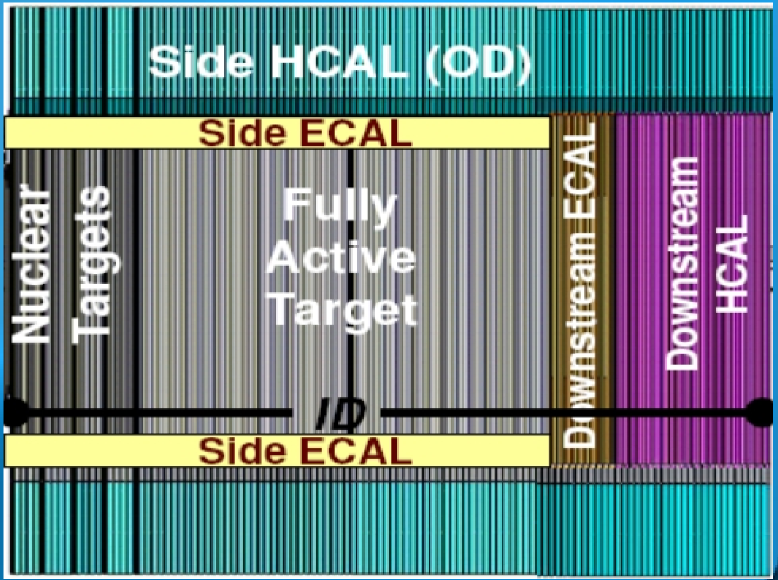
- ♦ Use data from muon monitors (goal of 10% precision on absolute flux)
- ♦ Take several special runs for different pion kinematics off the target (goal of 7% on shape and 10% on absolute flux)
- ♦ Use external hadron production data with extrapolation



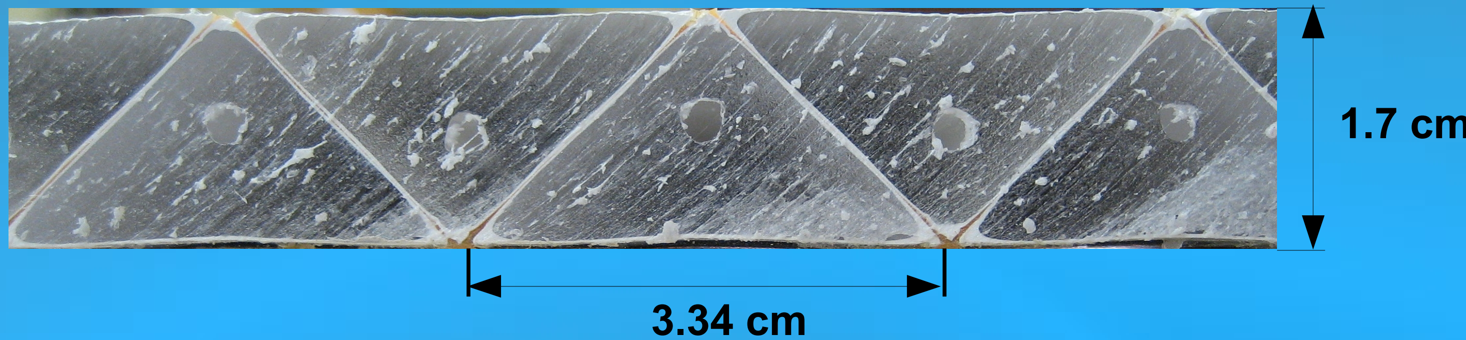


Detector description

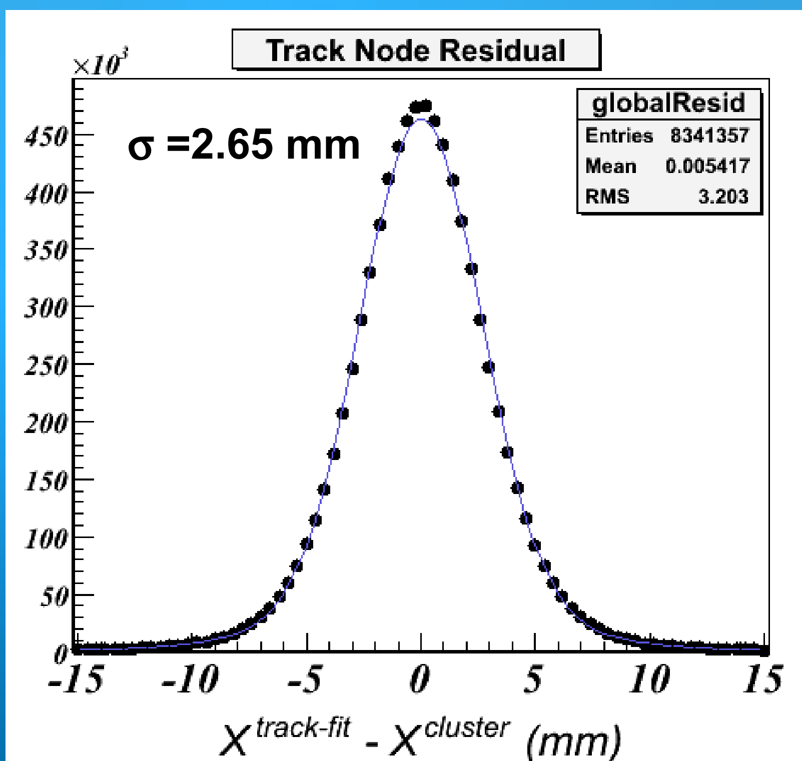
- Combination of fully-active fine-grained detector and calorimeter
- 120 modules in total (appr. 30K readout channels)
- Each module has inner and outer part
- 3 types of inner region:
  - Tracker module (2 scint. Planes + lead collar)
  - ECAL module (2 scint. Planes + 2 lead planes)
  - HCAL module (1 scint. plane + steel plane)
- Nuclear targets inside (C, Fe, Pb, H_2O) and in front (^4He) of the detector
- Veto wall to filter out the incoming particles from upstream interactions



Spatial resolution



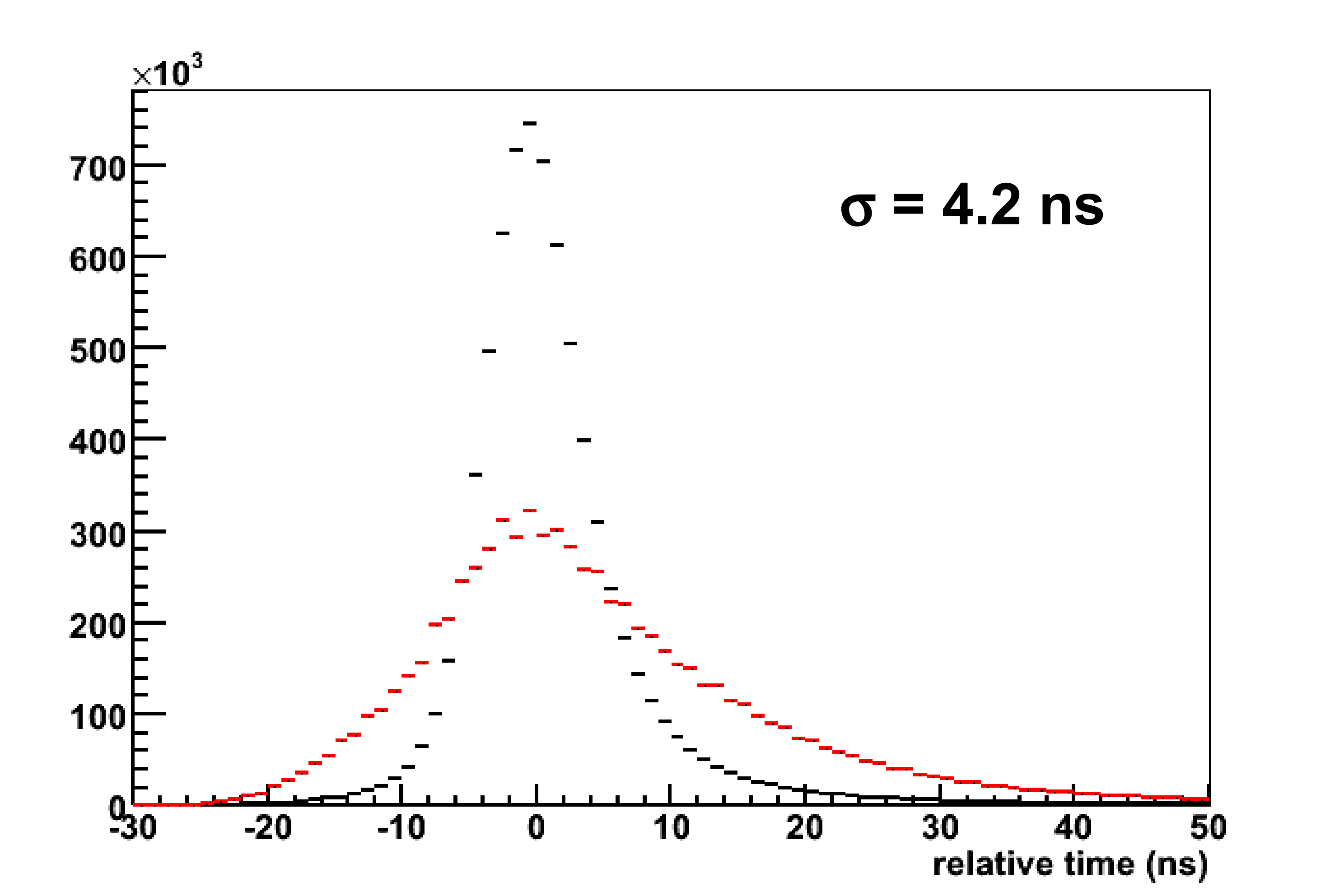
Transverse position resolution



- On a node-by-node basis, each node is removed and the track is re-fit
- The residual is the difference between the fitted and the actual node position

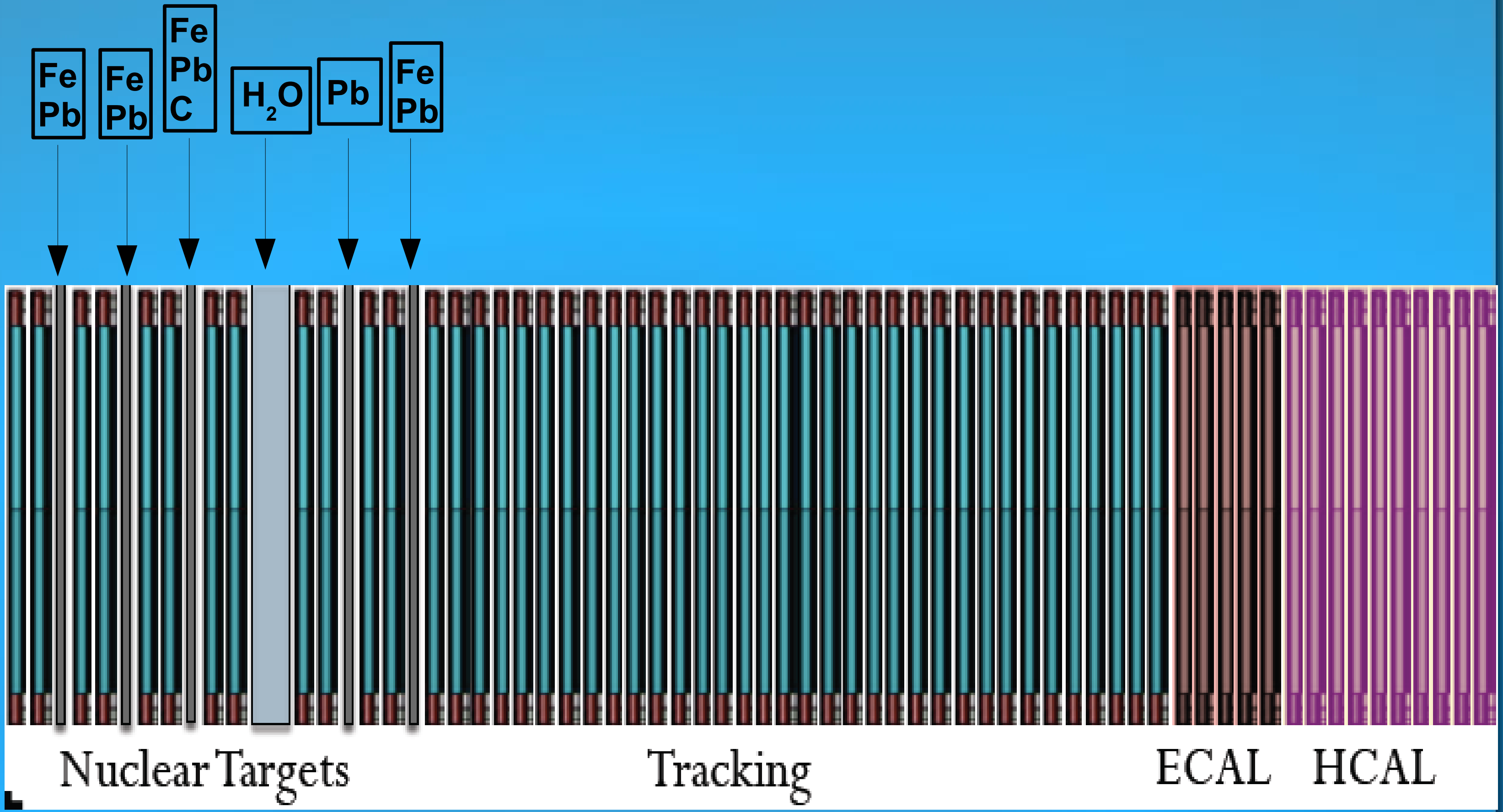
Timing resolution

Hit time on rock muon tracks relative to the average track time before (red) and after (**black**) timing corrections



Nuclear targets

^{4}He



- C, Fe, Pb incorporated into the body of the detector with scintillator modules in between the targets
- ^{4}He cryogenic target in front of the detector
- H_2O target is under construction

Event rates

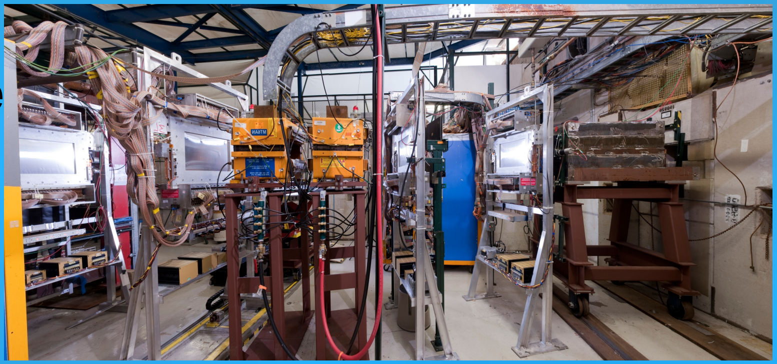
- 4.0E20 POT in low-energy; 0.9E20 in special runs; 12E20 in medium-energy beam configuration

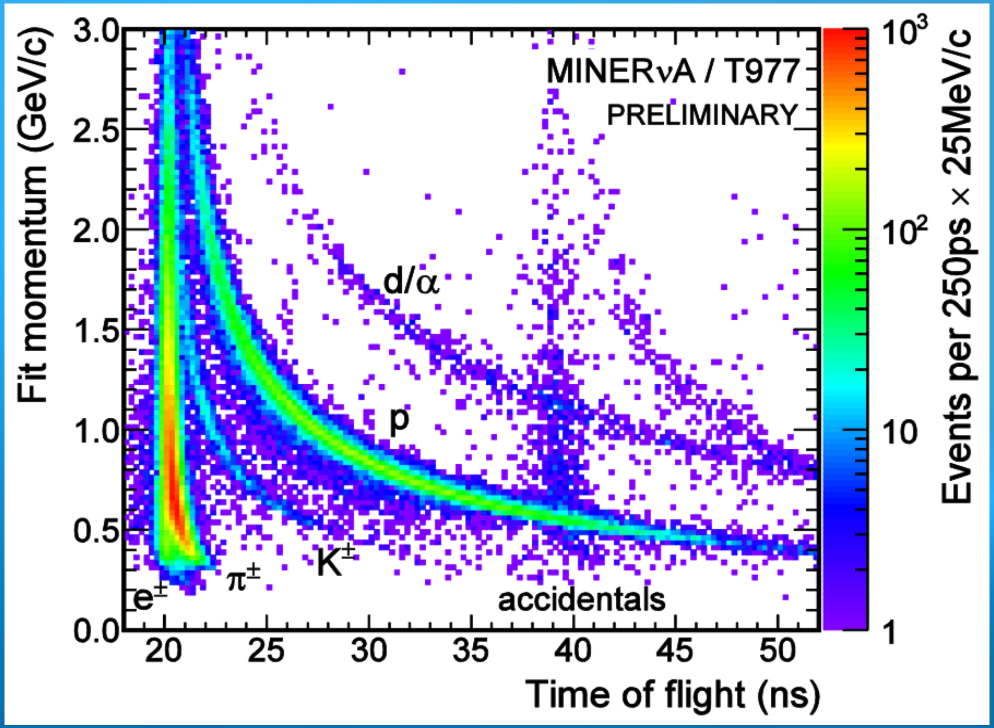
MC estimation for event rates in low-energy neutrino beam

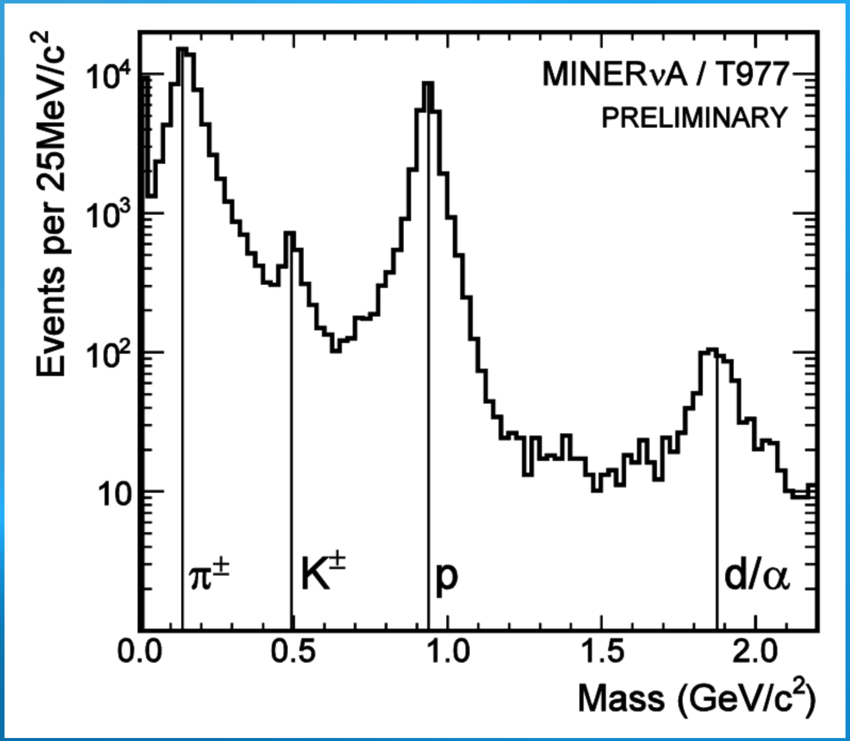
Target	Fiducial Mass	ν_μ CC Events in 1.2e20 P.O.T.
Plastic	6.43 tons	409k
Helium	0.25 tons	16.8k
Carbon	0.17 tons	10.8k
Water	0.39 tons	24.4k
Iron	0.97 tons	64.5k
Lead	0.98 tons	68.4k

Calibration - TESTBEAM

- Fermilab T977 Experiment
- 16 GeV pion beam on copper target produce tertiary beam (0.4 to 3 GeV) of π, p, K, etc
- Wire chambers, dipole magnets, ToF
- Aim is to calibrate absolute energy scale of MINERvA







Simulation overview

- Event generation - GENIE (takes numi flux files as input)

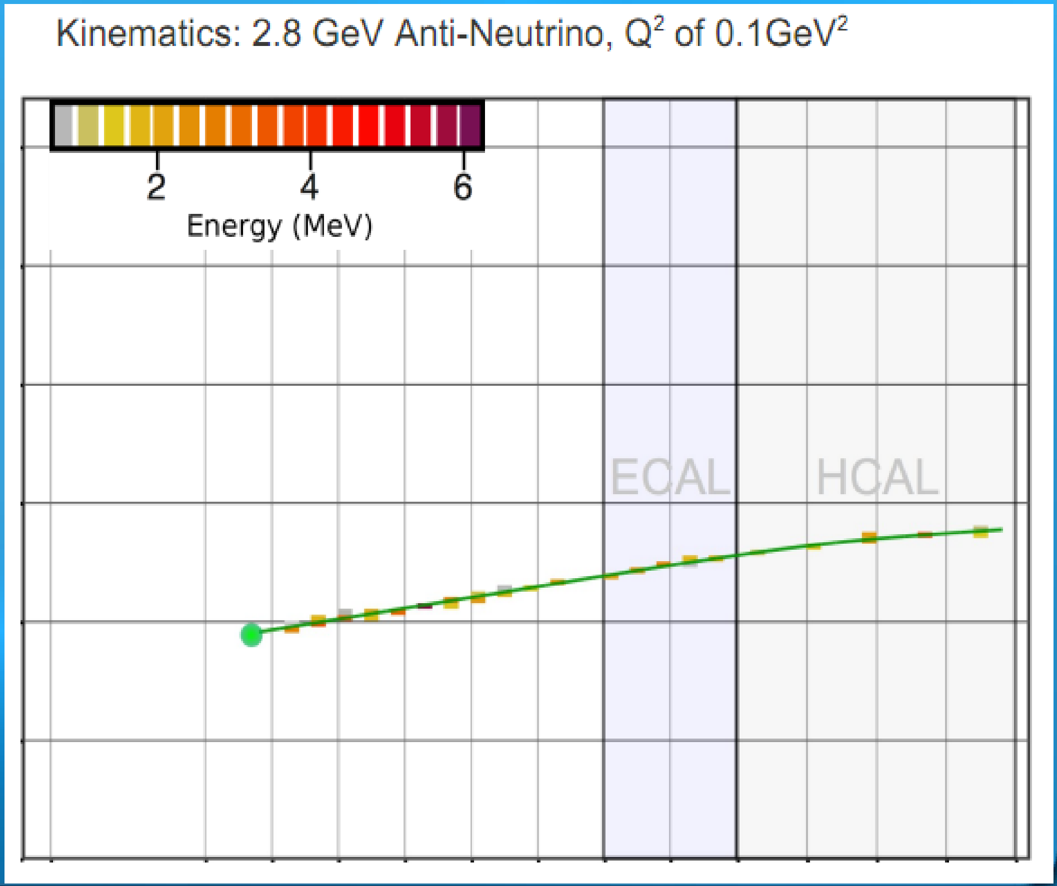
- Detector response - Geant4

- Electronics simulation:

  - OpticalModel (energy-to-light, attenuation, light-to-pe pulse)
  - PmtModel (pe pulse amplification, optical cross-talk)
  - FebModel (TRIP chips, discriminators, ADCs)

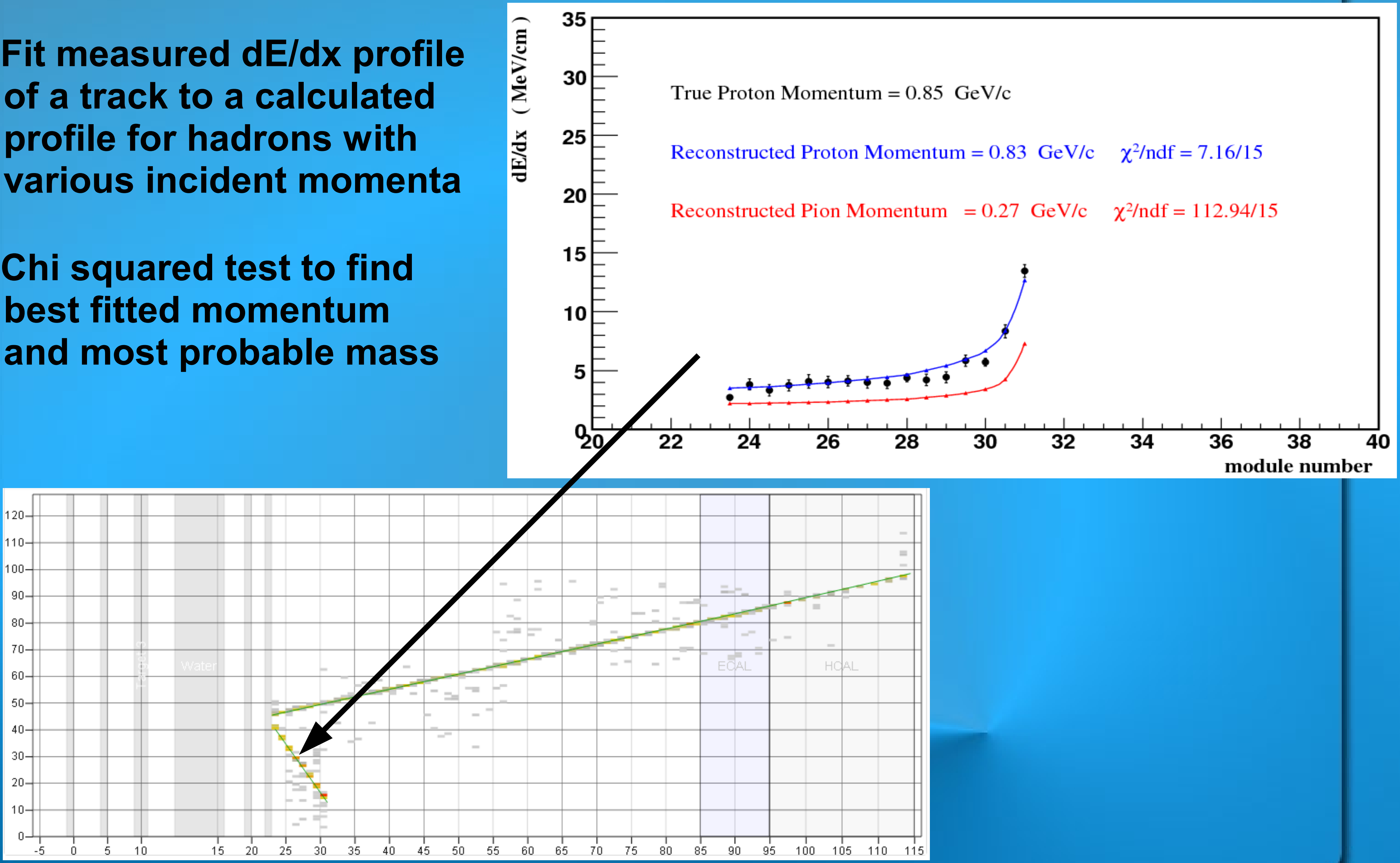
Reconstruction overview

- Performs time-slicing on the event (separation within time spill)
- Creates clusters – hits within a given plane
- Groups together clusters in the same view (X,U,V) – 2D tracking
- Combines 2D tracks to create 3D tracks
- Fits the resulting tracks
- Finds vertices
- Energy reconstruction (dE/dx)
- Tracks into MINOS
- Particle ID



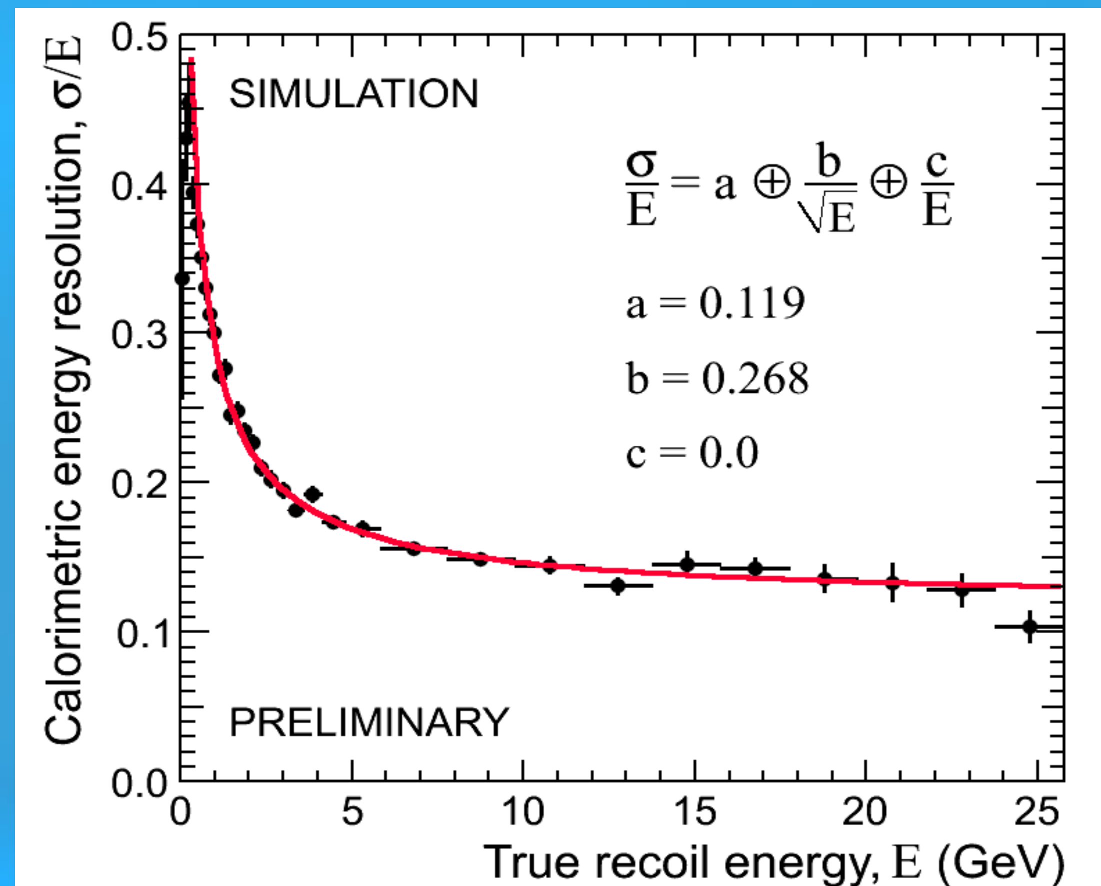
Reconstruction example

- ♦ **Fit measured dE/dx profile of a track to a calculated profile for hadrons with various incident momenta**
- ♦ **Chi squared test to find best fitted momentum and most probable mass**



Reconstruction example

- ♦ **Hadron calorimetry studies**
- ♦ **Visible energy in each subdetector (tracker, ECAL, HCAL) is summed. Each region is also weighted by a calorimetric constant**
- ♦ **MC for neutral current neutrino interactions**



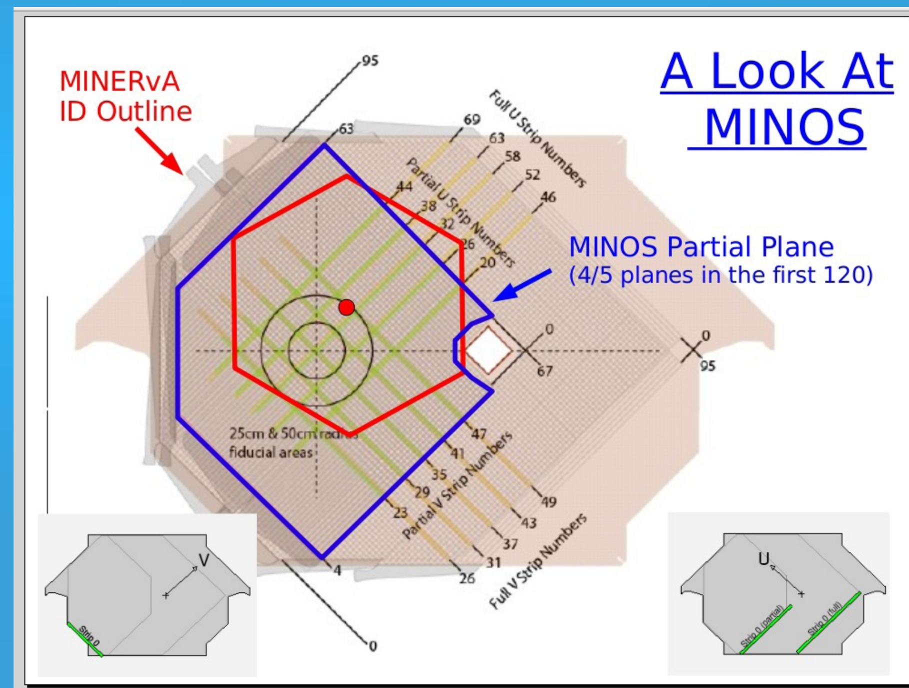
From MINERνA into MINOS

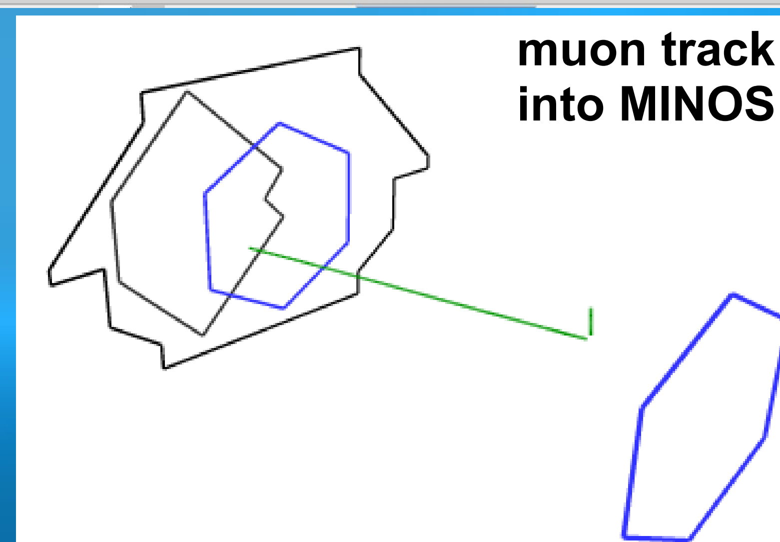
- MINOS near detector is very important to us. Many of the muons from interactions in MINERvA escape into MINOS

- Selection is done based on time stamps of events in two detectors

- Projects tracks from MINERvA into MINOS (and vice versa) and minimizes the distance between projections

- Able to find matches for ~ 95% of the tracks going into MINOS





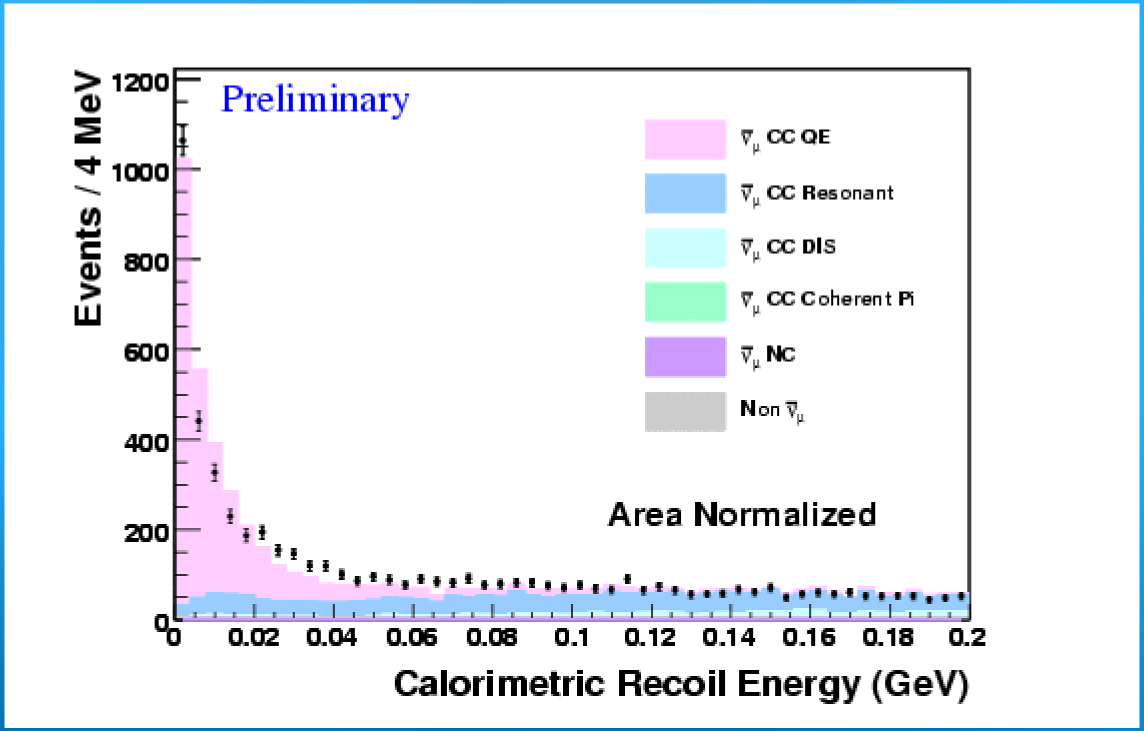
Current status – QE studies

- Anti-neutrino QE studies
- Partial-built detector geometry (60% of the full detector)
- 4E19 POT for data and 10E19 POT for MC
- Fiducial mass - 2.86 tons of plastic scintillator
- Event selection:
  - vertex in tracker region
  - MINOS-matched track
  - muon charge is positive
  - recoil energy cuts
- 5388 events after the cuts

Current status – QE studies

Calorimetric recoil energy

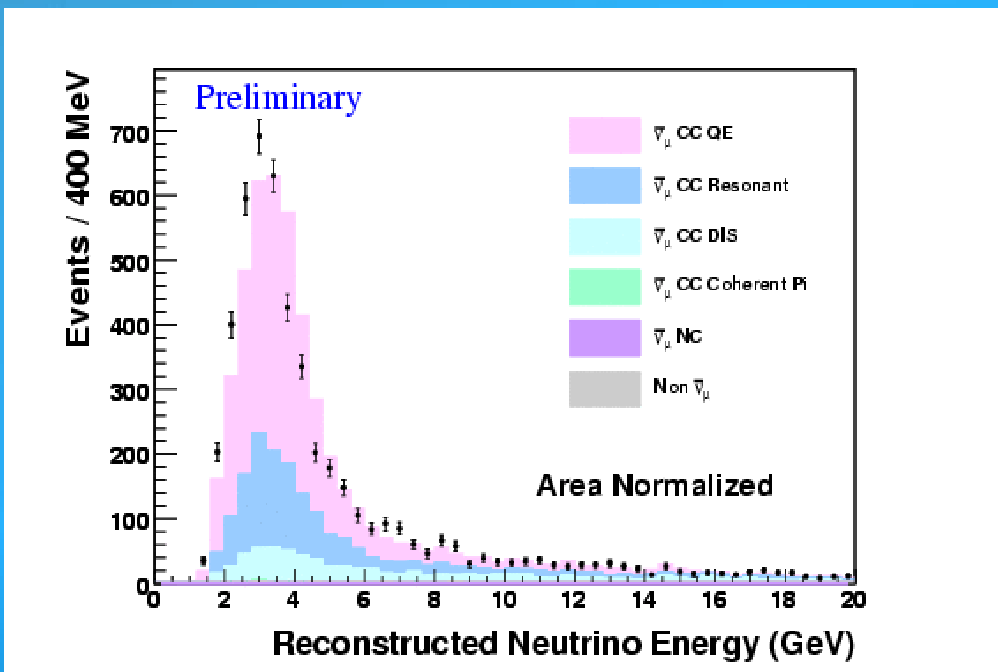
- Sum of the energy outside of the cylinder (5 cm radius, +/- 5 cm upstream/downstream) around muon track within track time window
- Require that this energy be less than calculated recoil energy



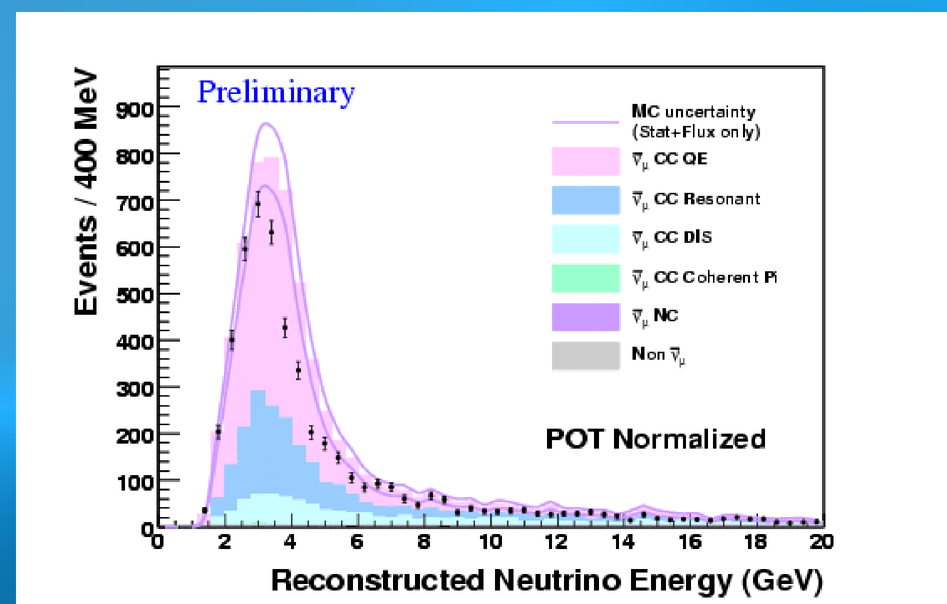
Current status – QE studies

Neutrino Energy: after recoil cut (QE enhanced sample)

area normalized



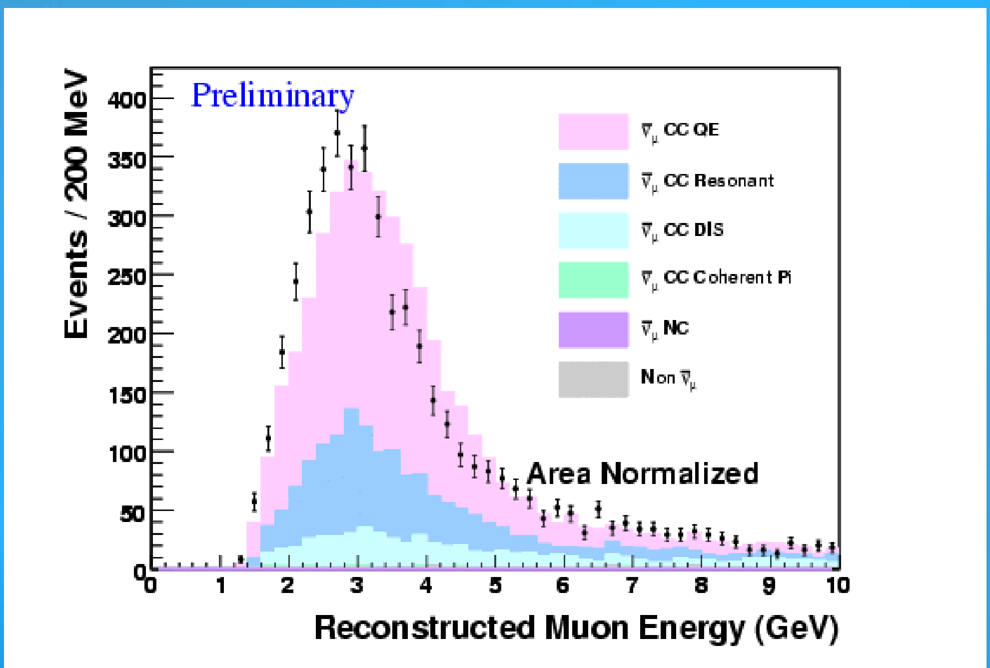
POT normalized



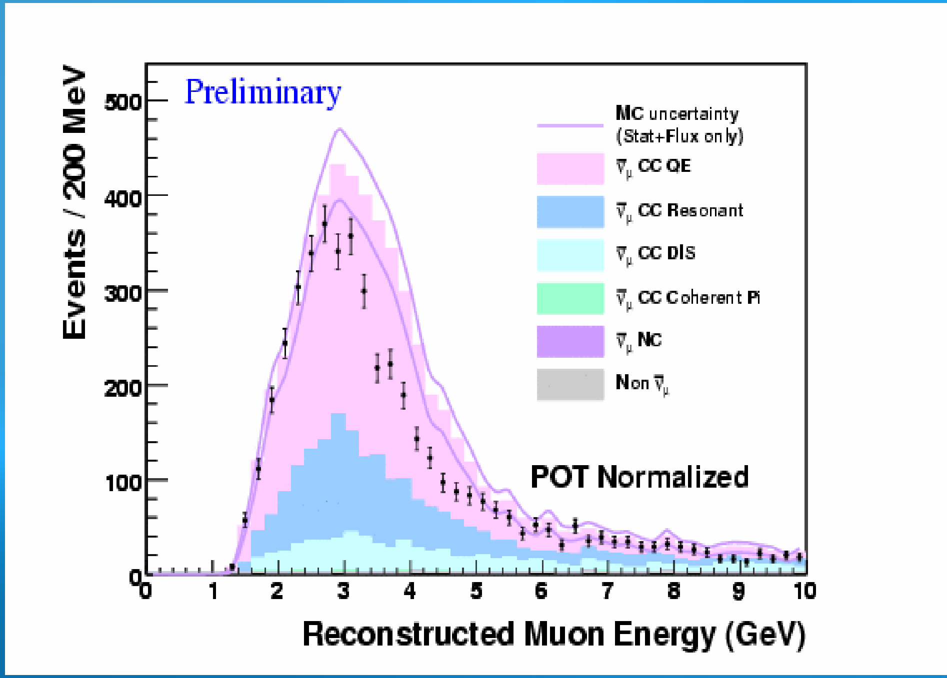
Current status – QE studies

Muon Energy: after recoil cut (QE enhanced sample)

area normalized



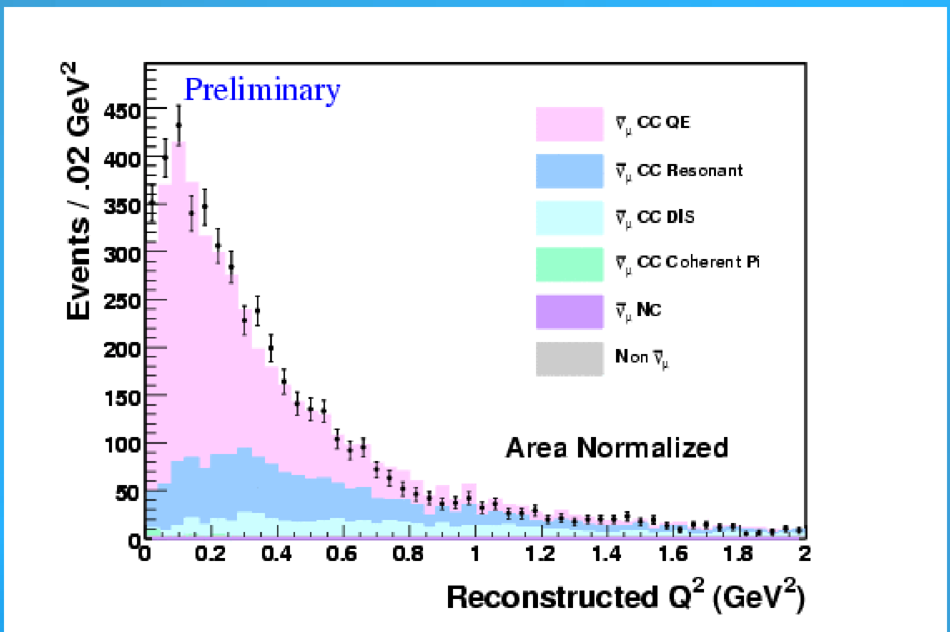
POT normalized



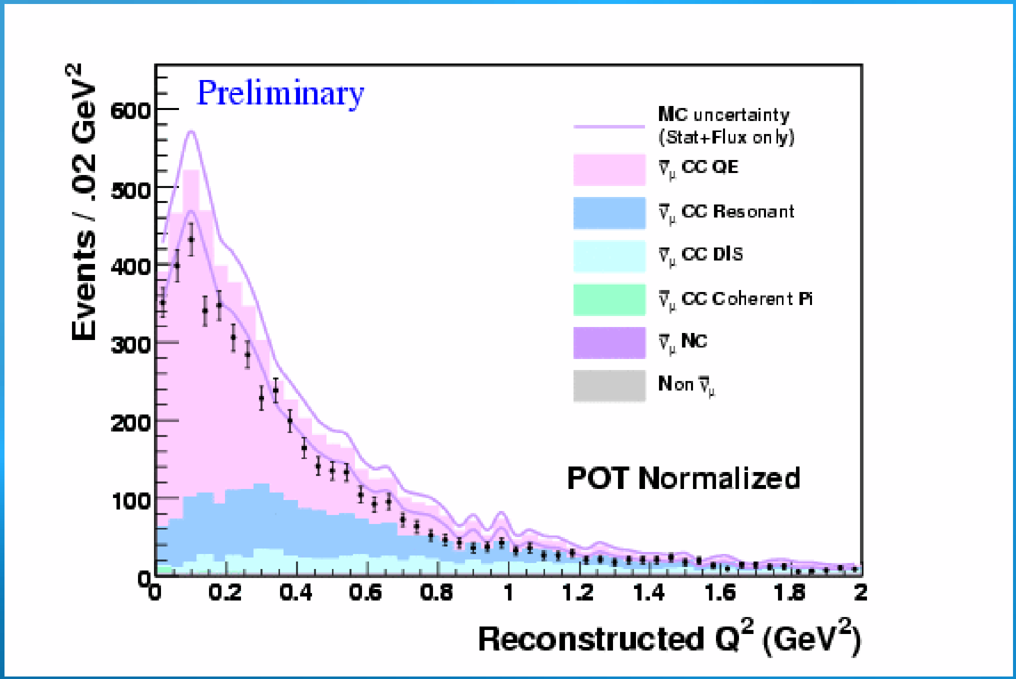
Current status – QE studies

Q^2: after recoil cut (QE enhanced sample)

area normalized



POT normalized

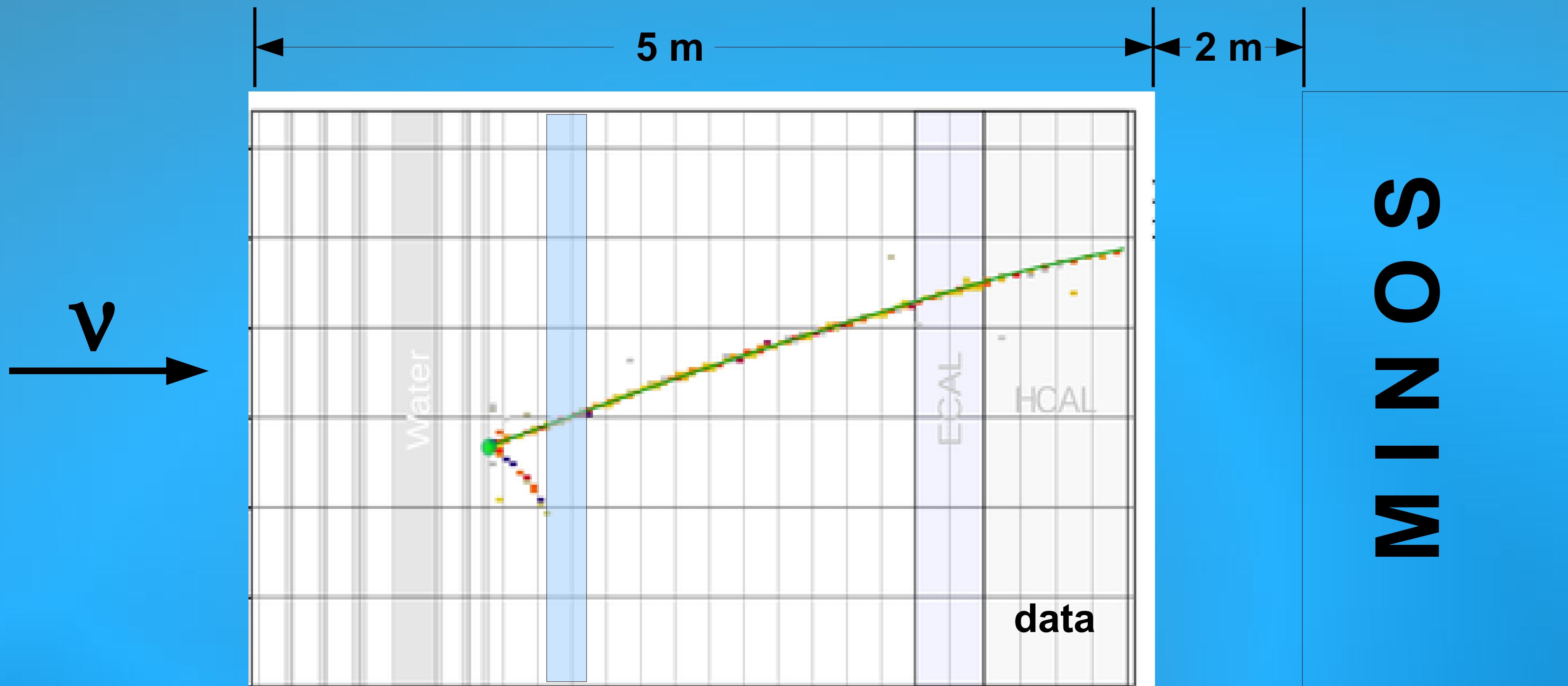


Current status – nuclear targets

Selection of events:

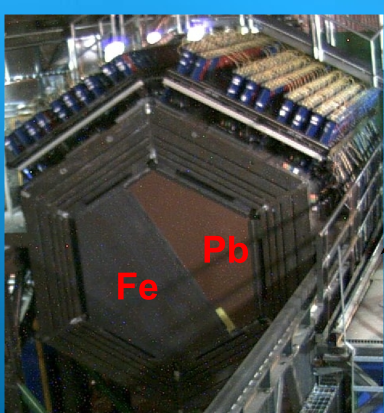
- Require that the muon is reconstructed in MINOS
- Require that the muon vertex is in the target or in the first module downstream of the target
- Require that the muon vertex is inside the 85cm fiducial radius
- Require that there is no muon-like activity upstream of the target
- The most downstream target only (Fe/Pb)
- This target is compared to “plastic reference target” (group of four active scintillator modules with the same divide as the real target)

Nuclear target event candidate



target 5
(Fe/Pb)

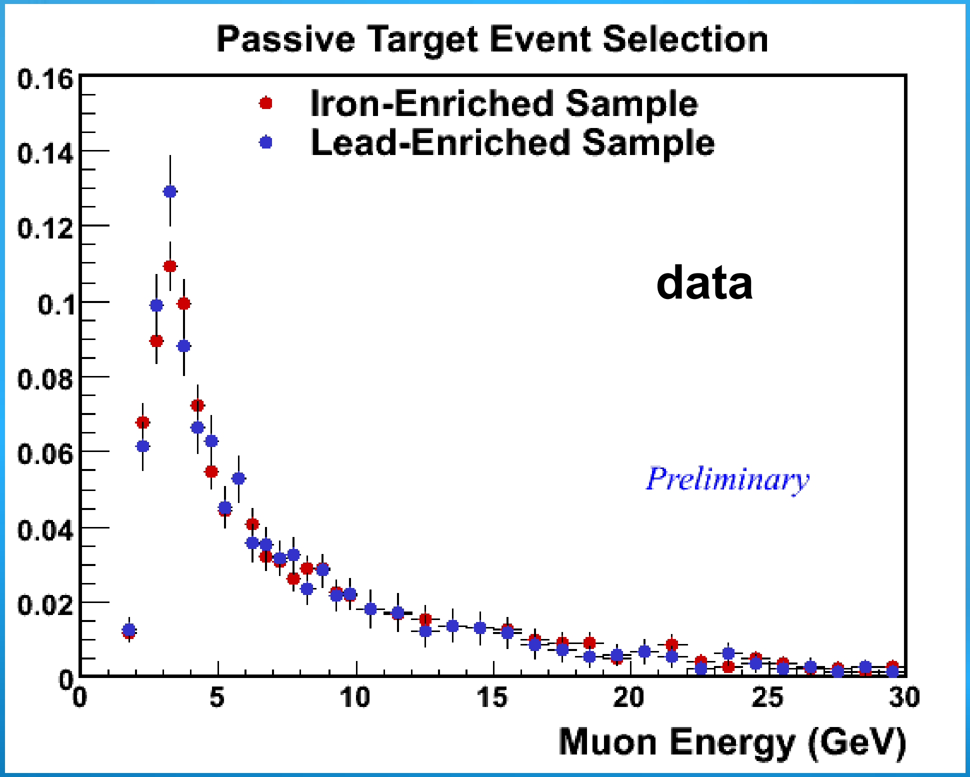
plastic
reference



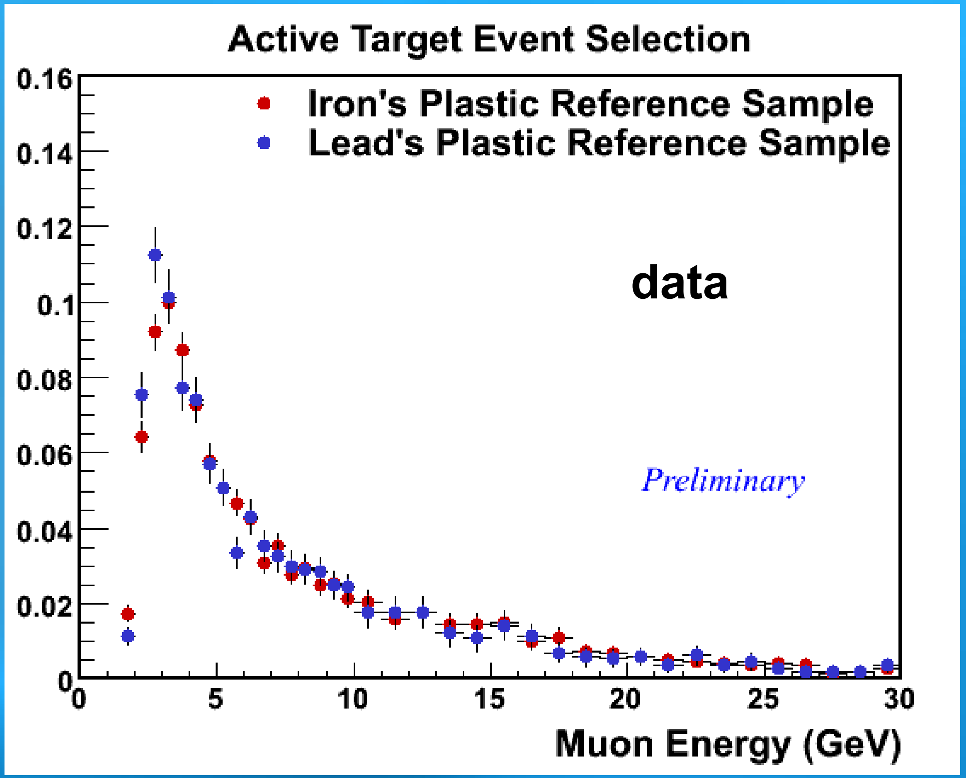
Current status – nuclear targets

Muon energy

passive target



plastic reference

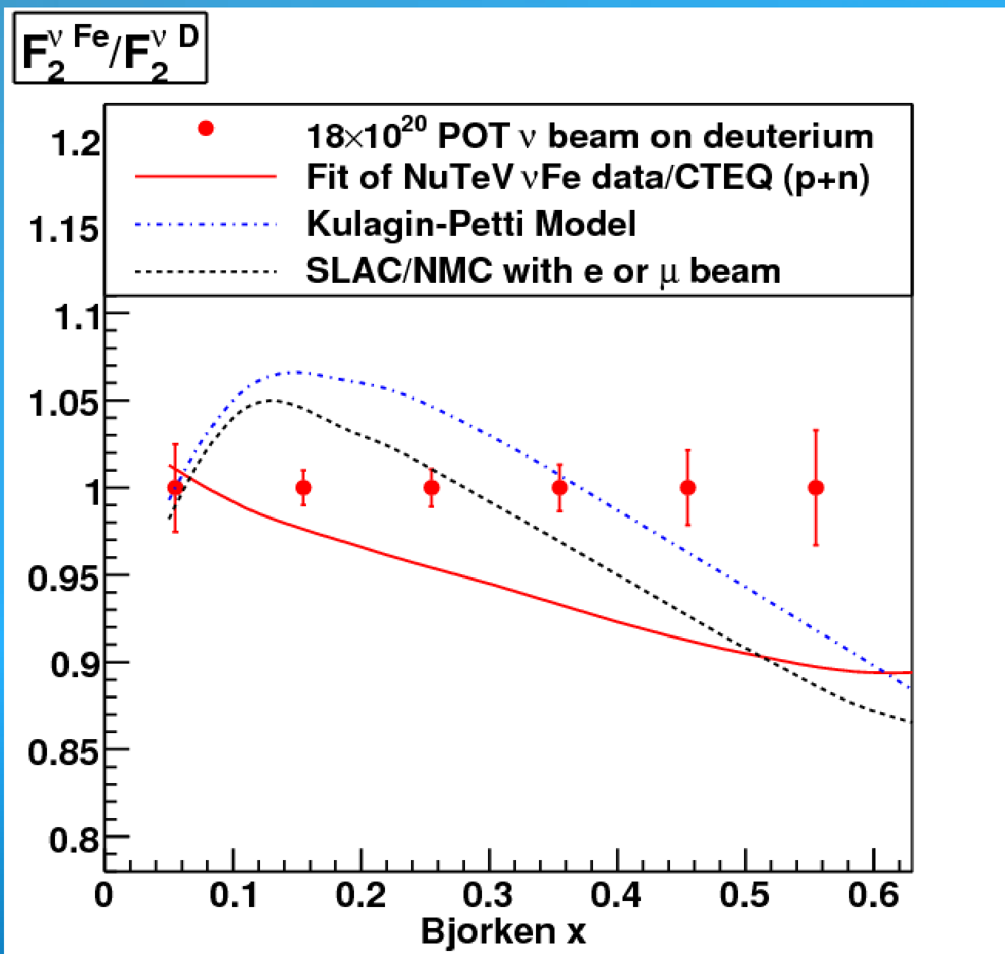


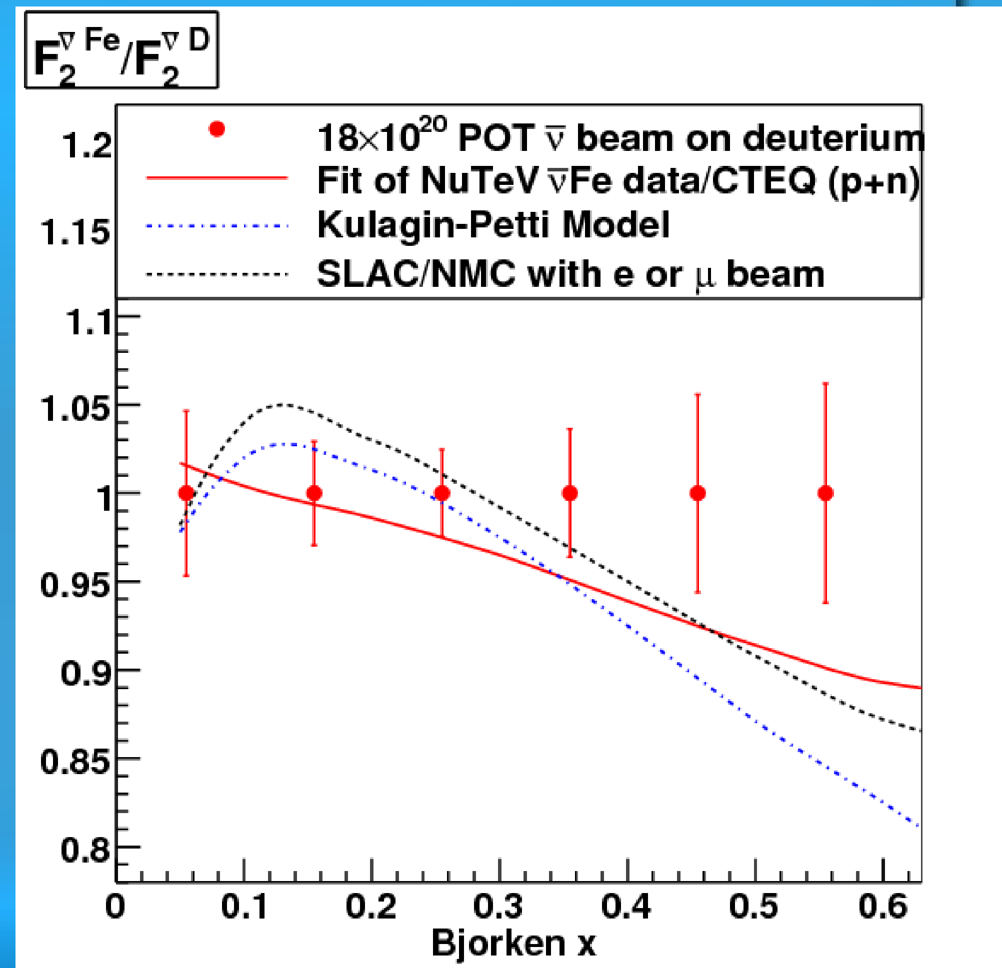
Future plans

- ♦ Data acquisition is underway
- ♦ Studies are undergoing on improving simulation and reconstruction routines
- ♦ Proposal to replace helium with hydrogen/deuterium target for ME running:
  - will contribute to understanding proton structure
  - no neutrino experiments with H2/D2 target since a long time ago
  - very high luminosity with NuMI beam
  - precise measurements on free protons
  - large part of hardware is ready

Deuterium target

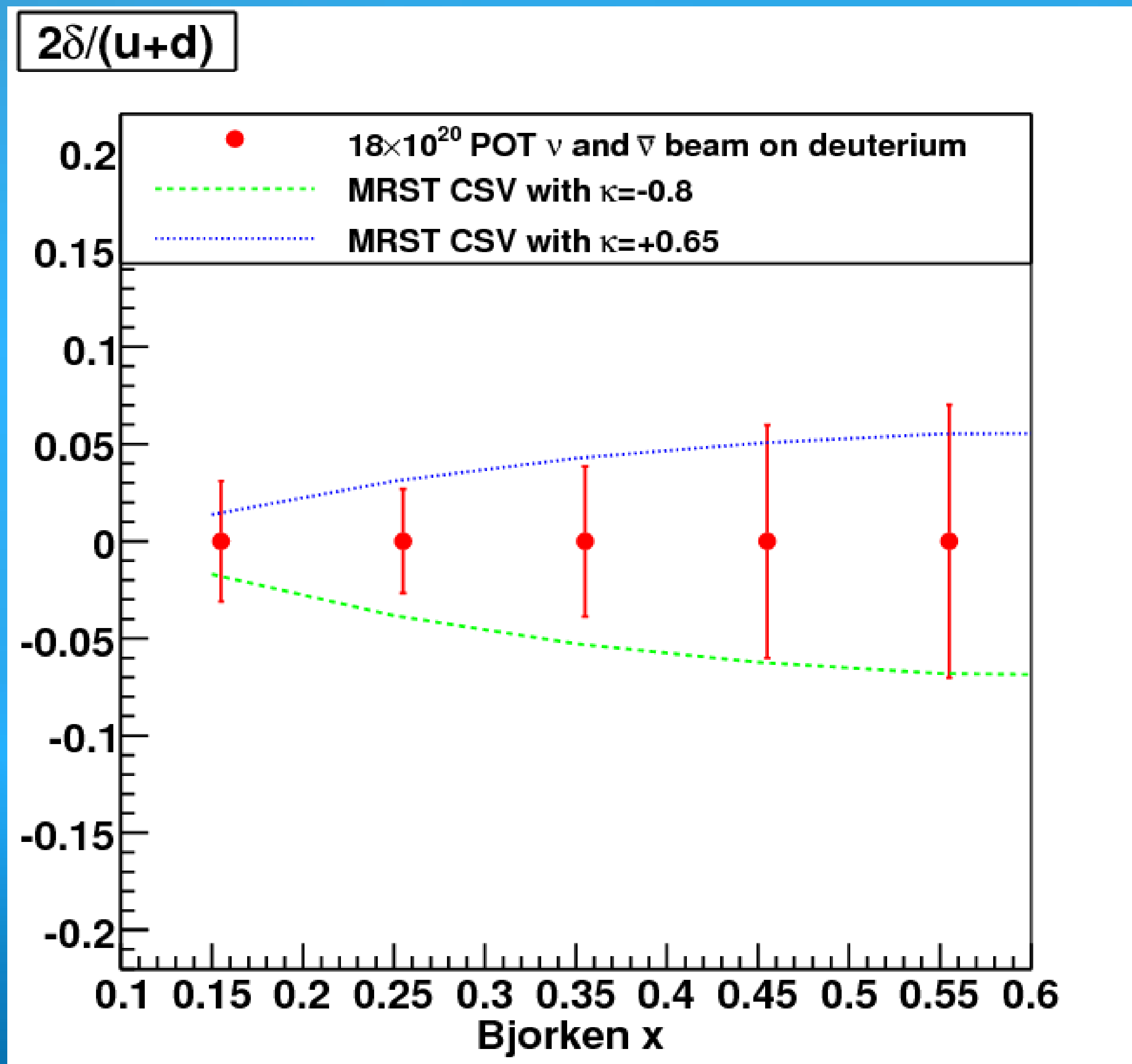
The projected A/D CC-DIS ratio





Deuterium target

The projected charge asymmetry measurement



Thank you for your attention

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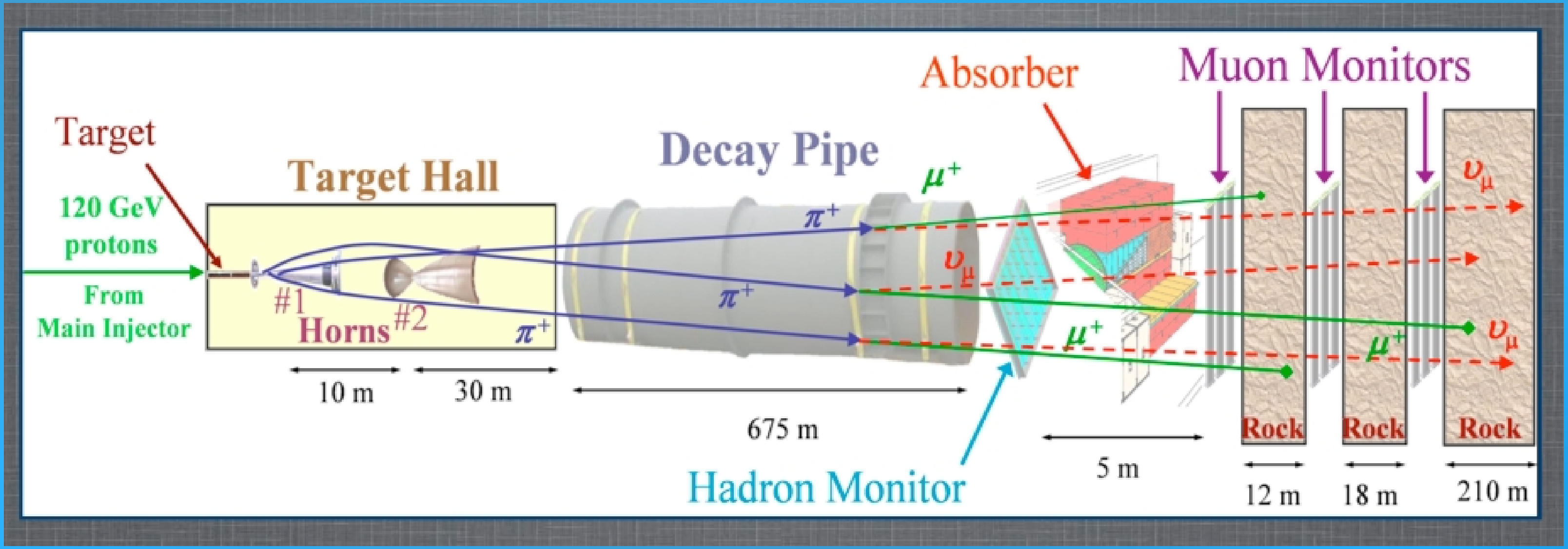
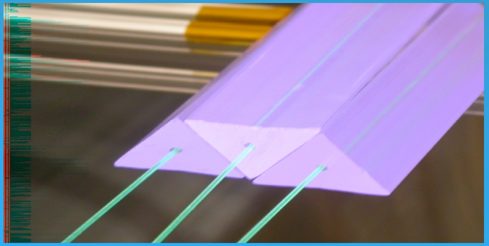
Backup slides

NuMI beamline

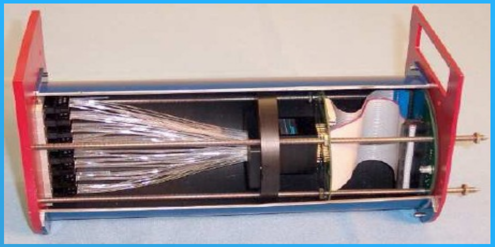


- ♦ **Target – graphite pellets, total length – 95 cm**
- ♦ **Two magnetic focusing horns for different beam configurations**
- ♦ **Decay pipe, absorber, hadron and muon monitors**
- ♦ **Target-detector distance – appr. 1 km**

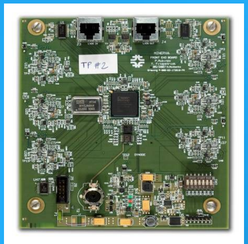
Detector description



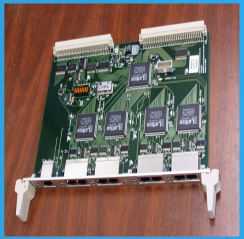
- Scintillation light is collected with WLS fiber inside a strip (inner part) or bar (outer part)



- M-64 multi-anode PMTs



- Front end board for signal amplification and digitization



- CROC/VME readout cards

- DAQ machine and storage

- Light-injection box for PMT gain measurements

Calibration overview (I)

- At the end of the readout chain, we have the digits with ADC counts. Need an energy deposited in a given channel (strip or bar)
- First of all, plex model is used to find the correspondence between the channel (electronics space) and the strip/bar (detector space)
- ADC counts to charge (uses database with FEB constants)
- From charge to raw photoelectrons (uses PMT gain tables)
- From raw pe to calibrated pe (uses attenuation data for clear and WLS fiber). Calibrates to the center of the strip
- After the reconstruction is done, the hit is further corrected for attenuation to the actual position in the strip

Calibration overview (II)

- Long muon tracks are used for alignment of the detector ("where we think the detector is" vs. "where the detector actually is")

- Muon tracks are used to strip-to-strip calibration to make the response uniform throughout the detector (light losses due to broken fibers, connector problems, etc.)

- pe-to energy conversion: using muons that propagate into MINOS, the conversion factor is derived to turn photoelectrons into energy

Calibration example

- An example of calibration – strip-to-strip
- Measures MeV/cm for rock muons in the detector. Removes non-uniformities due to light losses in bad connectors, etc. Uses alignment to get the pathlength of muons through the strip